

CHAPTER 10

OPERATING PRINCIPLES OF A REPRESENTATIVE SURFACE SEARCH RADAR AN/SPS-10D (PART I)

INTRODUCTION

This chapter presents a block diagram analysis of Radar Set AN/SPS-10D, and a block and schematic diagram consideration of the radar modulator, transmitter, and duplexer. The directional coupler and echo box used to obtain systems performance checks are also considered in the latter portion of the chapter.

Radar Set AN/SPS-10D (fig. 10-1) is used primarily in the detection, ranging, and tracking of surface targets. It can be used to a limited extent to provide the same information regarding air targets.

Target range and bearing intelligence is displayed on a standard Navy Plan Position Indicator (PPI). The AN/SPS-10D can be operated as a beacon or as an IFF (identification, friend or foe) system.

GENERAL DESCRIPTION

The functional operation of Radar Set AN/SPS-10D can be studied with the aid of figure 10-2. The modulator provides modulating pulses for the transmitter, and synchronizing pulses for the other units of the radar system. The transmitter, when triggered by the modulator output, transmits a series or burst of radio-frequency pulses (electromagnetic waves). This energy is radiated by a unidirectional rotating antenna reflector.

Radar Set AN/SPS-10D (fig. 10-1) operates in a frequency range of 5450 to 5825 mc (x-band). The pulsed output frequency is generated by keying a magnetron oscillator in the transmitter. The peak output power is between 190 and 285 kw.

During radar operation the output pulse duration is either 0.25 or 1.3 μ s ($\pm 10\%$). The pulse repetition rate (prf) can be adjusted between 625 and 650 pulses per second. Approximately 0.08 μ s of each magnetron keying pulse is required to place the magnetron in operation.

Thus, the width of the input trigger pulses are 0.33 and 1.38 μ s, respectively.

For beacon operation, the pulse duration is increased to 2.25 μ s, and the prf is decreased from 312 to 325 pulses per second. The total duty cycle of the system (ratio of pulse duration time to pulse repetition time) must be maintained at less than 0.001 to permit magnetron recovery time.

The beacon function of the radar set permits operation of the system in conjunction with responding ships or aircraft. The response signals are mixed in the beacon receiver with the beacon local oscillator output and are ultimately presented on the indicator. The received signal is therefore stronger, and causes bright spots in the indicator pattern. These bright spots are used to identify a responding object.

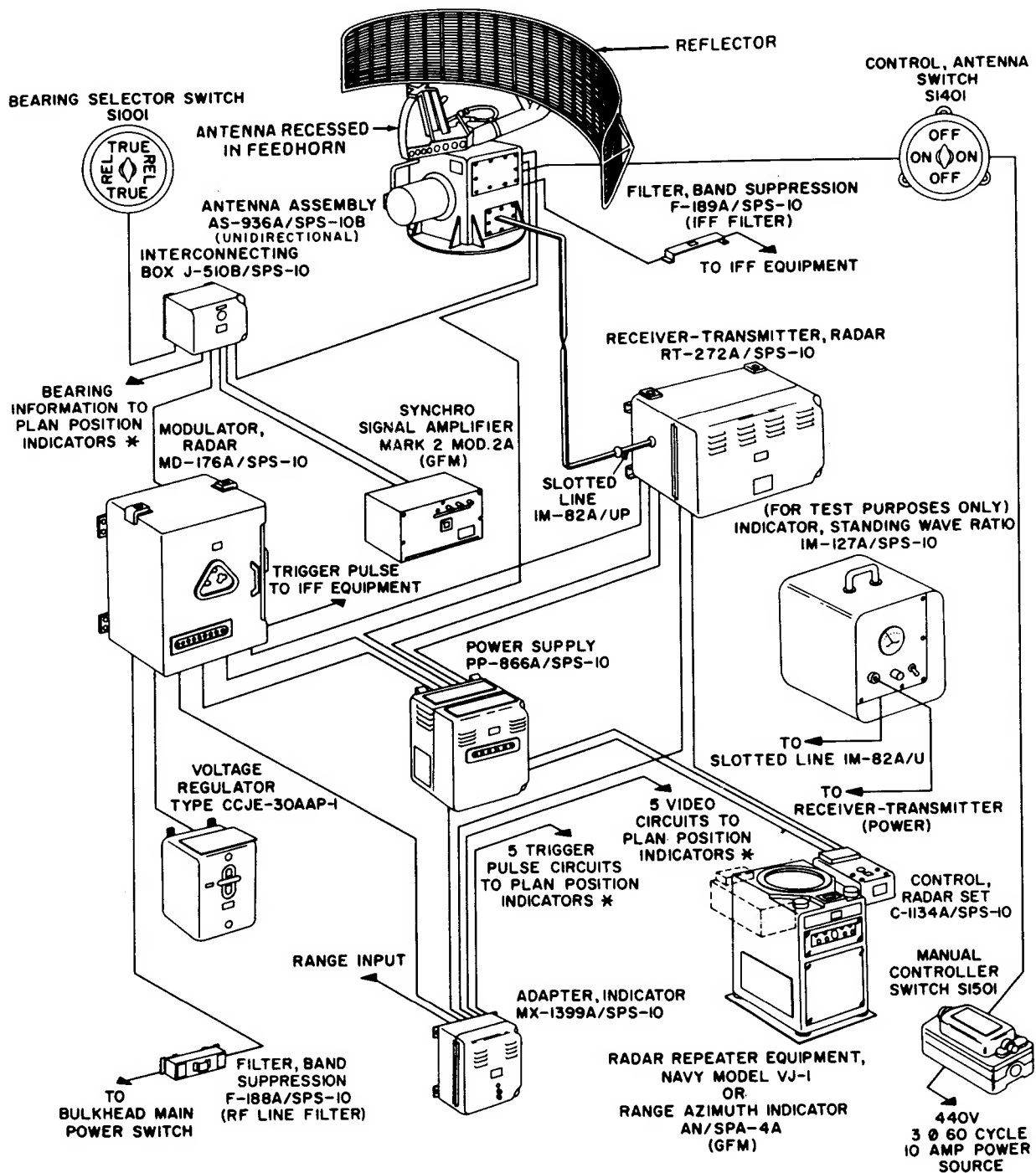
The antenna rotates at 15 rpm. During radar operation, the horizontal beam width of the radiated pattern is approximately 1.5 degrees. The vertical beam width is within 12 to 16 degrees.

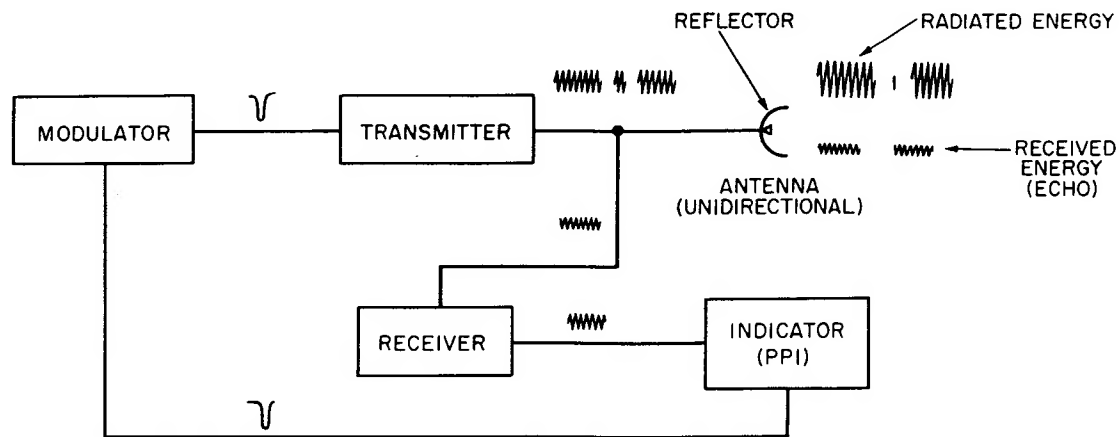
RADAR SET AN/SPS-10D DETAILED BLOCK DIAGRAM

The detailed block diagram, figure 10-3, shows all of the major units of Radar Set AN/SPS-10D. The main system flow is indicated by heavy lines, and supplementary circuits by light lines.

The following consideration of the block diagram emphasizes the purpose and relationship of all major units of the radar system. A detailed block diagram of each major unit is presented before the discussion of the major circuits of that unit.

Synchronizing trigger pulses for the radar set are obtained from the modulator. The primary a-c power is fed to the modulator through an r-f line filter. This filter serves to eliminate the transfer of r-f noise from the a-c





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Figure 10-2.—Radar Set, AN/SPS-10D, functional diagram.

power source to the radar set and from the radar set to the power source.

An electronically controlled voltage regulator maintains the a-c power input voltage at 115 volts \pm 2 percent. A power supply converts the a-c input voltage into regulated and nonregulated d-c voltages for distribution to the various circuits.

The modulator pulse output is formed in any one of three pulse forming networks (shown later), each of which produces pulse outputs of different time durations. The main pulse output is a negative-going rectangular pulse which is fed to the transmitter. The transmitter then develops r-f pulses of either 0.25, 1.30, or 225 μ s as determined in the pulse forming network selected at the modulator. The length of the transmitter trigger pulses is sufficient to compensate for the delay in the starting of the transmitter.

The negative pulses (main pulses) generated in the modulator are applied to a pulse transformer in the transmitter, where the amplitude is increased from 5 kv to approximately 20 kv.

The pulses from the transformer are applied to a magnetron oscillator with no change in the original waveform polarity. Application of the pulses to the magnetron places the magnetron in operation, and causes it to generate microwave r-f energy for a time interval equal to the length of each input pulse, minus the time required to key the magnetron (0.08 μ s).

The modulator also provides low amplitude differentiated samples of the main pulses. These pulses are applied along one path to an adapter indicator. Other samples of the main pulse from the modulator are used for synchronizing external and auxiliary equipments which

may operate in conjunction with the radar set.

In the adapter indicator, the trigger pulses are delayed to compensate for the time delay between the trigger pulse generated by the modulator and the actual transmission of the microwave r-f pulse. After delay, the trigger pulse is amplified and applied to five conventional cathode-followers. The output pulses are used separately to trigger as many as five plan position indicators.

The microwave r-f output energy of the magnetron oscillator is conducted to the antenna assembly through a duplexer, a slotted line, and a rectangular waveguide. This energy is then directed by a feed-horn (fig. 10-1) to the surface of a slotted parabolic reflector.

During transmission, the antenna reflector concentrates and radiates the energy into space in a narrow beam pattern. The pattern forms a horizontal angle at the reflector of approximately 1.5 degrees and a vertical angle of from 12 to 16 degrees. The antenna pattern is formed by phase addition and subtraction of the microwave r-f energy components radiated to its surface by the feed-horn.

The antenna rotates at 15 rpm. The transmitted beam sweeps over the surrounding area to search for both surface and airborne targets within the limits of the antenna reflector.

When the radiated energy strikes a target, a small portion returns to the antenna reflector. The reflector directs this reflected energy to the receiver (fig. 10-3) through the waveguide, slotted line, duplexer, and t-r cavity. The t-r cavity acts as an automatic electronic shorting switch to block the receiver from the high-energy r-f pulses of the transmitter while the

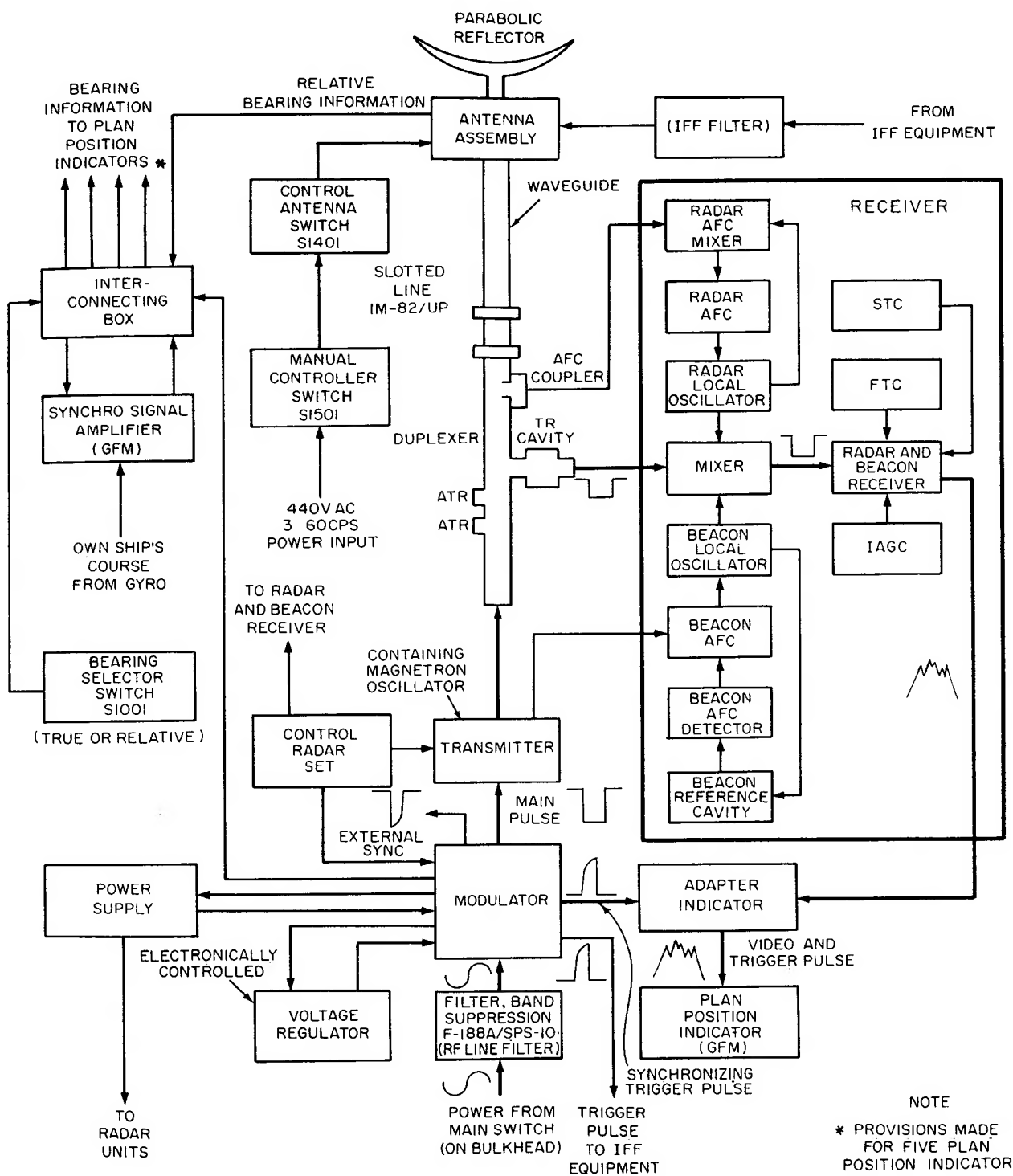


Figure 10-3.—Radar Set, AN/SPS-10D, detailed block diagram.

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transmitter is radiating, and to unblock the receiver to the waveguide while the transmitter is not radiating.

Two a-t-r (anti-t-r) tubes, located near the magnetron oscillator in the transmitter, present a high impedance to the returned signal energy (echo), thus preventing dissipation of the returned signal at the magnetron oscillator during the receiving interval.

The returned echo is fed to a mixer stage, where it is mixed with a signal from either the radar or beacon local oscillator. The radar local oscillator operates on a frequency 30 mc higher than the returned signal frequency or 5480 to 5855 mc. The beacon local oscillator operates at a single frequency (5420 mc) or 30 mc below the received beacon signal. For either radar or beacon operation, the difference frequency component at the output of the mixer is selected and amplified by the i-f amplifiers in the receiver.

Since the radar and beacon local oscillators are coupled to the same mixer, the use of a common i-f amplifier section for either radar or beacon reception is possible. Either the radar or beacon local oscillator is turned on independently for the desired type of operation.

After amplification and detection in the receiver, a video output signal from the receiver is delivered to the adapter indicator. The output from the adapter indicator can be used to operate as many as five plan position indicators.

The adapter indicator output is applied to the control grid of the cathode-ray tube in the PPI and causes intensity modulation of the electron beam. The target signal is thus converted into visible intelligence on the screen of the PPI scope, where it appears as a bright spot.

Automatic frequency control (afc) circuits are provided for the radar and beacon local oscillators. The function of the radar afc circuit is to maintain the frequency of the radar local oscillator 30 mc higher than the magnetron frequency, regardless of minor drifts in the magnetron frequency. The radar afc circuit compares the radar local oscillator and magnetron frequencies in a circuit which produces a voltage to correct the radar local oscillator for the proper intermediate frequency. The beacon afc circuit ensures that the beacon local oscillator operates 30 mc below the magnetron frequency during beacon operation.

The sensitivity time control (stc) circuit is of value in reducing saturation of the i-f stages due to strong echoes from the sea at close ranges (sea-return saturation) so that nearby targets can be distinguished. The stc circuit reduces

the gain of the receiver instantaneously in coincidence with each transmitted pulse. The gain is reduced for only a short period of the sweep time and is permitted to rise exponentially to normal gain so that weak echoes from distant targets will receive normal amplification in the receiver. The stc circuit does not affect the presentation on the plan position indicator of targets which are beyond the stc range. The time interval needed to fully restore the receiver gain limits the period over which the stc can remain effective after each transmitted pulse.

The fast time constant (ftc) circuit makes it possible to distinguish more clearly individual small targets (short duration) in an area of large targets having considerably longer durations. This feature is useful when there are many strong close-in targets. The ftc circuit differentiates all return signals in a short time constant circuit and causes each signal to be of approximately equal duration.

An instantaneous automatic gain control circuit (iagc) prevents strong signals from saturating the i-f amplifiers. The iagc circuit reduces the gain of the i-f amplifiers for the duration of the strong received signal.

The bearing selector switch provides a means of selecting either true or relative bearing information for presentation on the plan position indicators. Relative bearing information is fed from an antenna synchro (not shown) through the interconnecting box to the plan position indicators. Relative bearing information is also fed to the synchro signal amplifier.

The synchro signal amplifier combines the relative bearing information from the antenna synchro and own ship's course information from the ship's gyro compass to present true bearing information on the plan position indicators.

The manual controller switch is a power switch used to start and stop antenna rotation. The switch also contains an overload relay which removes power from the antenna when the current reaches an overload value. The control antenna switch also removes power from the antenna and is mounted on the ship's mast below the antenna. The switch is intended for use by maintenance personnel to remove antenna power during maintenance procedures.

The IFF filter minimizes interference from the radar set to the IFF equipment which may be used in conjunction with the AN/SPS-10D.

MODULATOR

The modulator of the AN/SPS-10D (fig. 10-4) provides four pulses:

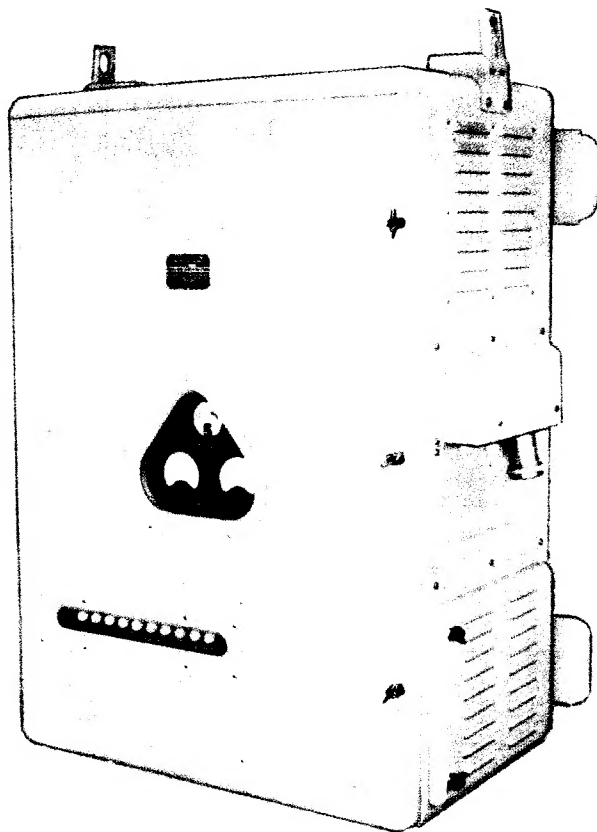


Figure 10-4.—Modulator.

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1. A negative 5 kv modulating pulse (50-ohm termination) of variable width for transmitter (magnetron) operation. (One of three pulse widths may be selected.)
2. A 25- to 50-volt positive trigger pulse (50-ohm termination) for synchronization of IFF equipment.
3. A 25- to 50-volt positive trigger pulse (75-ohm termination) for synchronization of the indicator adapter.
4. A 150-volt negative pulse (75-ohm termination) for synchronization of other external equipment used in conjunction with the radar set (such as test equipment).

BLOCK DIAGRAM

The modulator (fig. 10-5) comprises two major sections, namely, the trigger pulse generator and the modulator pulse generator. The trigger pulse generator supplies a +150-volt trigger pulse to the modulator pulse generator causing the latter to produce the output

modulating pulse to the transmitter and auxiliary equipments.

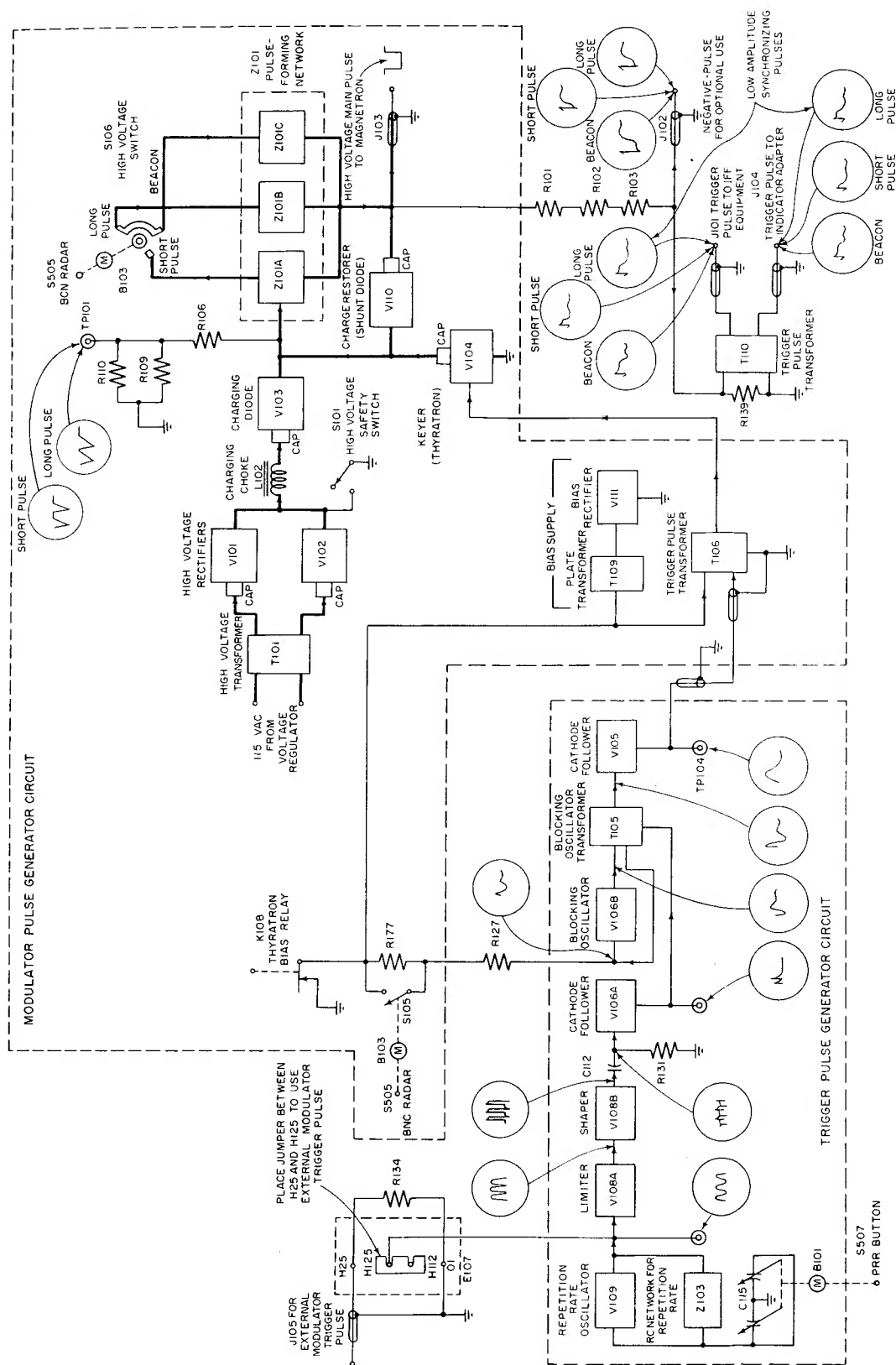
Synchronization of all units of the radar set is controlled by a low-power repetition rate (master) oscillator, V109. This oscillator supplies a sine wave to limiter, V108A, at a selected repetition rate between 625 and 650 cps. An r-c network, Z103, in conjunction with a prr control determines the oscillator output frequency and the resulting pulse repetition rate.

Limiter, V108A, clips the sine wave. Shaper, V108B, converts the clipped sine wave input into a square wave output. The square wave is differentiated by R131 and C112 into sharp voltage spikes. Positive portions of the spikes are reproduced at the V106A cathode and fed through T105 to the blocking oscillator V106B input. These pulses trigger the blocking oscillator, V106B, to produce a negative-going output at the T105 primary. The T105 secondary output pulse is positive-going to cathode follower, V105. The positive-going V105 +150-volt output is fed through T106 and serves as a trigger pulse for keyer thyatron, V104. The pulse is 4 μ s in duration and has a sharp leading edge.

The modulator pulse generator circuit produces a high voltage main pulse (and the low-amplitude synchronizing pulses for external and auxiliary equipments) at a rate determined by the trigger pulse to the keyer thyatron, V104. Thus, the V104 trigger pulse rate is the same as the repetition rate of oscillator, V109. Thyatron, V104 keys a high voltage circuit by periodically short-circuiting the high voltage output at the V104 trigger pulse rate.

The high voltage rectifier of the modulator pulse generator comprises T101, V101, and V102. This supply charges pulse forming network, Z101, through charging choke, L102, and charging diode, V103, to approximately 7 kv. The charging diode presents an easy charge path (during the time that the rectified pulsating d-c voltage is rising) but a high discharge resistance when the high voltage pulse tries to decrease. Thus, the pulse forming network cannot lose its charge until V104 fires.

Thyatron, V104 operates as a coincidence stage, and requires the simultaneous application of the high voltage at its plate and the input trigger pulse from T106 at its control grid. The conduction of V104 reduces the V104 plate voltage to ground, and a low resistance path exists in parallel with the charged Z101 network. Thus, Z101 discharges through the conducting resistance of V104. The output pulse from Z101 to



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Figure 10-5.—Modulator, block diagram.

The main pulse output at J103 can be adjusted by S505 and S106 for the short, long, or beacon pulse widths. These pulses are 0.33, 1.38, and 2.33 μ s, respectively.

At the end of the V110 conduction, charging diode, V103, again conducts to charge Z101. The charge restores diode, V110, remains non-conductive until the end of the next pulse.

reverse (positive) residual charge across Z101 would increase in magnitude with the application of each subsequent pulse. The action would accumulate a charge across V104 which would eventually result in thyatron arc-over or a breakdown of the components in the pulse forming network.

REPETITION RATE OSCILLATOR

A simplified schematic circuit diagram of the trigger pulse generator in the modulator is shown in figure 10-6. The repetition rate oscillator, V109, is connected as a conventional phase-shift oscillator. The repetition rate of the oscillator is determined by the r-c network



Figure 10-6.—Modulator trigger pulse generator.

comprising Z103 and C115. The network gives a 180 degree phase shift from plate to grid of V109 at 650 cps.

Prr switch, S507, is used as a push-button control for prr motor B101. The motor, when energized, drives the tuning capacitor, C115. This action tunes the oscillator from 625 to 650 cps.

LIMITER-SHAPER

Because a sharp trigger pulse is required to fire the thyatron keyer tube, V104, in the modulator pulse generator (fig. 10-5) the sine wave output of V109 must be shaped in limiter-shaper, V108, and blocking oscillator, V106, to develop a trigger pulse. Limiter, V108A, begins the shaping action which produces a square wave.

The operation of V108A and V108B is similar to that of a 2-stage over-driven amplifier. The square wave output from the plate of V108B has the same repetition rate as that of the oscillator V109. The square wave output is differentiated by C112 and R131 into a 2 μ s pulse.

Diode CR101 limits the amplitude of the positive pulse applied between the grid and cathode of V106A. Note that the cathode of CR101 is tied to the junction of R115 and R130 which forms a voltage divider between the +300 volt B supply and ground. The potential to ground at the CR101 cathode is thus maintained at about 22 volts. The cathode of V106A is held at 11 volts to ground (near cut off) by the V106A cathode follower conduction through R126.

The cathode of V106B is held at +22 volts by its connection at the top of R130. The grid of V106B is returned to ground via R127, S105, and K108. Hence, the bias on V106B is approximately -22 volts and the tube is nonconductive.

Positive input portions of the differentiated square wave cause V106A conduction to increase and a positive-going output pulse is developed across R126 at the V106A cathode. If the input pulse exceeds approximately +22 volts, CR101 will conduct and prevent any further increase in the input signal. The positive pulse across R126 serves as the input trigger pulse to V106B. Diode CR102 prevents the application of negative-going pulses to the V106A grid.

BLOCKING OSCILLATOR

Stage V106B operates as a conventional single-swing blocking oscillator. The stage is normally cut off by the fixed voltage at the R115-R130 junction which is applied between the

grid and cathode of V106B through the normally closed contacts of K108, the 5-9 contacts of S105 and R127.

A positive pulse from V108 causes a positive pulse to appear at the cathode of V106A. The output of V106A drives V106B into conduction, and plate current goes to saturation and then to cutoff as a single swing blocking oscillator.

The blocking oscillator, V106B, recovery is set by the r-c time constant in the grid circuit, and determines the maximum rate at which the oscillator can be triggered. For normal radar operation, the grid r-c time constant is set by R127 and C114, and the V106B output frequency is the same as the repetition rate of V109.

When operating as a beacon interrogator, contacts 5 and 9 of S105 are open and an additional resistor (R177) is inserted in series with R127 in the grid circuit. The grid recovery time is increased to a value which permits every other pulse at the blocking oscillator grid to produce a V106B output pulse. The output pulse width is approximately twice the width of the radar long pulse (or 2.68 μ s). This necessitates a decrease in repetition rate to one-half the normal radar operating rate in order to keep the duty cycle less than 1 msec in a 1 second period. The time spacing between pulses is necessary to ensure thyatron (V104) de-ionization and total dissipation in the magnetron.

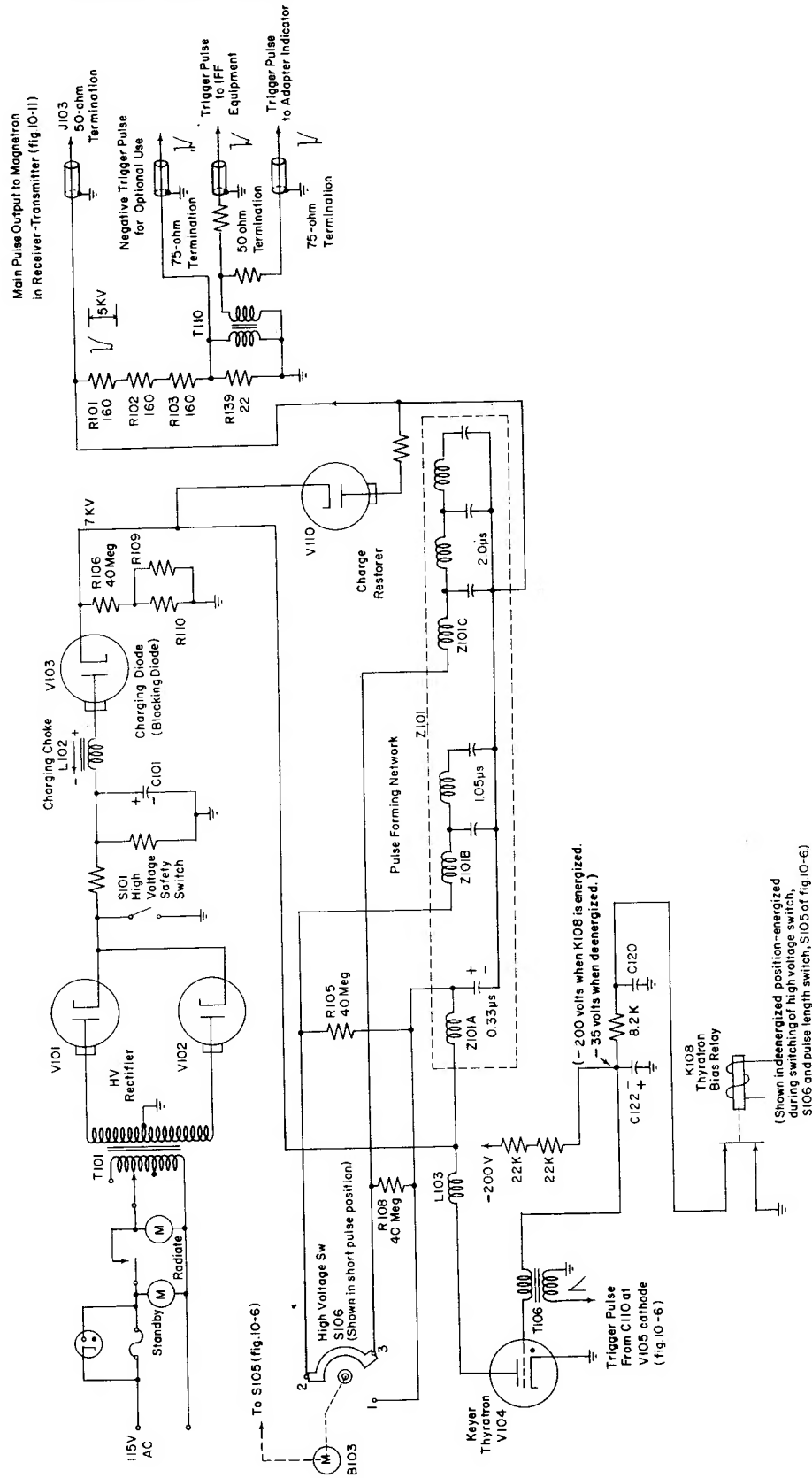
When pulse length switch, S105, is rotated to change the width of the trigger pulse, the contacts on thyatron bias relay, K108, open during the switching operation. This momentarily removes the ground from R127 and applies -200 volts to the V106B grid. This bias aids in cutting off the blocking oscillator during the switching operation.

The V106B output pulse (in the 4-2 winding of T105) has a steep positive-going leading edge which is fed through cathode follower, V105, to keyer thyatron, V104 (fig. 10-7). Resistor R133 (fig. 10-6) limits the V105 grid current during conduction.

MODULATOR PULSE GENERATOR

The modulator pulse generator (fig. 10-7) produces a high voltage keying pulse for keyer thyatron, V104. The V104 output, in conjunction with Z101 output, produces negative pulses which are delivered to the magnetron oscillator in the transmitter and to the indicators and auxiliary equipments used in conjunction with the radar set.

High voltage d-c for the pulse generator is produced in a conventional full-wave rectifier



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Figure 10-7.—Pulsing circuit and pulse network.

circuit comprising T101, V101, V102, and C101. Charging diode, V103, permits a charging current through L102 and the delay line during the first 90 degree rise of the rectified input half-cycle, and blocks any flow of current through L102 during the second 90 degree period when the input is falling. The voltage at V103 cathode is approximately 7 kv. This voltage is fed to the input of pulse forming network, Z101, and to the plate of V104.

Pulse forming network, Z101, consists of three sections (Z101A, Z101B, and Z101C). The sections provide pulse widths of 0.33, 1.05, and 2.0 μ s, respectively.

The action of high voltage switch S106 is to combine the sections of Z101 to produce the short, long, or beacon pulse output. The switch is shown in the short pulse position and the output pulse from Z101A is 0.33 μ s.

Resistors R105 and R108 provide a discharge path for the capacitors of Z101B and Z101C when the equipment is deenergized. When the equipment is operating, the voltage across the capacitor of Z101A is also applied through series resistors R105 and R108, respectively, to the B and C sections of Z101. However, because of the large value of these resistors (each 40 megohms) and the resulting long r-c charge time, no appreciable voltage is developed across Z101B and Z101C when S106 is in the short pulse position as shown.

To select the long pulse time (1.38 μ s) in Z101, S106 is turned so that its 1-2 contacts are shorted. This action adds Z101B to the pulse forming network and the pulse duration of Z101 is increased. Simultaneously, R105 is shorted. The total discharge time of the combined A and B sections of Z101 is 1.38 μ s.

The selection of the beacon pulse (2.33 μ s) is accomplished by combining the A and C sections of Z101 through the 1-3 contacts of S106.

Switches S106 (fig. 10-7) and S105 (fig. 10-6) are used in the selection of the magnetron trigger pulse length from Z101 (fig. 10-7) as discussed. These switches are motor driven by B103. A section of S105 (not shown) keeps B103 energized during switching.

Thyratron bias relay, K108 (fig. 10-6), energizes during switching to remove the short across C120 via the K108 contacts. The capacitor (C120) immediately charges to -200 volts, obtained from a bias supply (not shown). Relay, K108 remains energized during switching, and the negative voltage across C120 is applied to the grid of the blocking oscillator, V106B, and to the grid of thyratron keyer tube V104 (fig. 10-7). When B103 stops, K108 deenergizes, and

the bias on V106B and V104 returns to normal after the new charge time of Z101 has been selected.

The positive voltage developed from the top of Z101 to ground is applied to the V104 plate through L103. During normal (no-switching) operation, -35 volt bias is applied between the grid and cathode of V104.

As stated earlier, V104, in order to go into conduction, requires the simultaneous application of the positive voltage from Z101 at its plate, and the positive-going trigger pulses from T106 at its grid. When both voltages are applied to V104, the tube fires and places a low resistance path across Z101. The discharge path includes the magnetron (paralleled by R101, R102, R103, and R139), the conducting resistance of V104 and L103. The output from Z101A to ground is a negative-going pulse of approximately 5 kv. This output appears at J103, and is fed to the magnetron, V3001 (fig. 10-11) via cable clamp E3018, and pulse transformer T3002.

TRANSMITTER

The transmitter and receiver of Radar Set AN/SPS-10D are operated from the same antenna and duplexer.

The overall view of the receiver-transmitter is shown in figure 10-8. The r-f system is shown in figure 10-9. Frequent reference to these illustrations will be helpful in understanding the material presented in the remaining portion of this chapter and in chapter 11 as well.

TRANSMITTER BLOCK DIAGRAM

The block diagram of the transmitter section of AN/SPS-10D is shown in figure 10-10. The negative-going 5 kv pulse from the pulse forming network, Z101 (fig. 10-7) is fed via J103 to the primary of the pulse transformer, T3002, where it is stepped up in the secondary to 20 kv and applied to the magnetron, V3001 (fig. 10-10). The magnetron produces an r-f output between 5450 and 5825 mc for the duration of the input trigger pulse.

R-f energy from V3001 is fed through the duplexer, W3010, to the antenna and antenna reflector. The duplexer contains two tubes V3003 and V3004, a directional coupler, and a radar afc coupler with adjustable attenuator (not shown). The duplexer is of the branch guide type, that is, with arms leading to the antenna, receiver, and transmitter. Duplexing components are broad-band and do not require tuning.

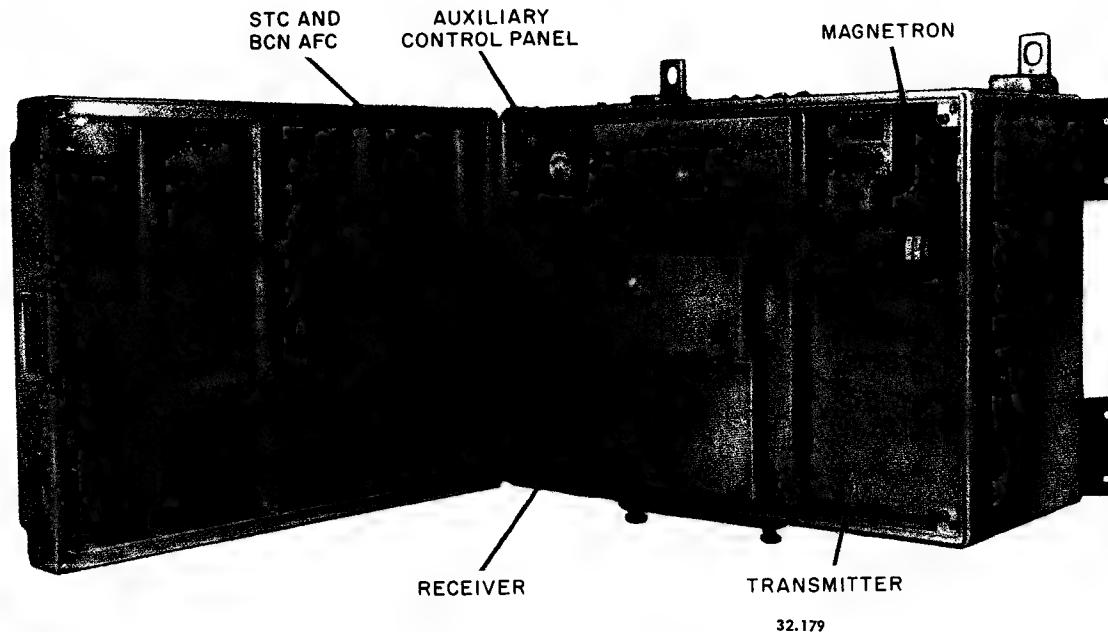


Figure 10-8.—Receiver-transmitter.

A choke joint (air gap) couples the duplexer to the magnetron.

The directional coupler absorbs a small amount of the transmitted energy from the duplexer and feeds it to the echo box, Z3013. The echo box is a device which stores a small amount of the transmitted r-f energy during transmission and feeds this energy to the receiver immediately after the transmitting period. This energy is released from the echo box as a ringing signal and will be reproduced on the radar indicator as a long continuous signal which begins at zero range and extends out several thousand yards. At an undetermined range on the indicator the echo signal decreases to the same magnitude as the background noise. The range at which the echo signal cannot be distinguished from the noise is indicative of the overall performance of the system. The greater the range reading, the better is the system performance.

The radar afc coupler supplies a small amount of the transmitted signal to the afc circuit in the receiver. This energy is used to keep the local oscillator operating at a given difference frequency (30 mc) with respect to the magnetron frequency output of the transmitter.

TRANSMITTER CIRCUIT ANALYSIS

The -5 kv pulse from J103 of the modulator (fig. 10-7) is fed through E3018 (fig. 10-11) to

the primary of pulse transformer, T3002. The input pulse duration is 0.33, 1.38, or 2.33 μ s, depending upon the combination of the sections in the pulse forming network as discussed. The T3002 secondary voltages are approximately 20 kv. The parallel windings equalize the voltage on both sides of the magnetron filament. Filament transformer, T3001, provides 11 volts for the magnetron filaments through the bifilar (noninductive) secondaries of T3002. The cathode and filaments are tied together to prevent arcing between these electrodes by large potential differences.

The polarity at the 5 and 6 terminals of T3002 when a pulse is applied, is always negative with respect to the 3 and 4 terminals, respectively. The magnetron oscillates for the duration of the pulses.

The magnetron is manually tunable over its frequency range (5450 to 5825 mc). This feature is desirable so that the operating frequency can be changed to minimize interference from other radar sets operating at the same frequency. The magnetron provides a minimum r-f peak power output of 160 kw.

The high-power high-frequency pulse from the magnetron passes to the duplexer, W3010, through a choke joint (air gap). The air gap (not greater than 0.060 inch) allows for expansion of components (without appreciable loss of transmitter power) and avoids the necessity of hand-fitting parts when a new magnetron is installed.

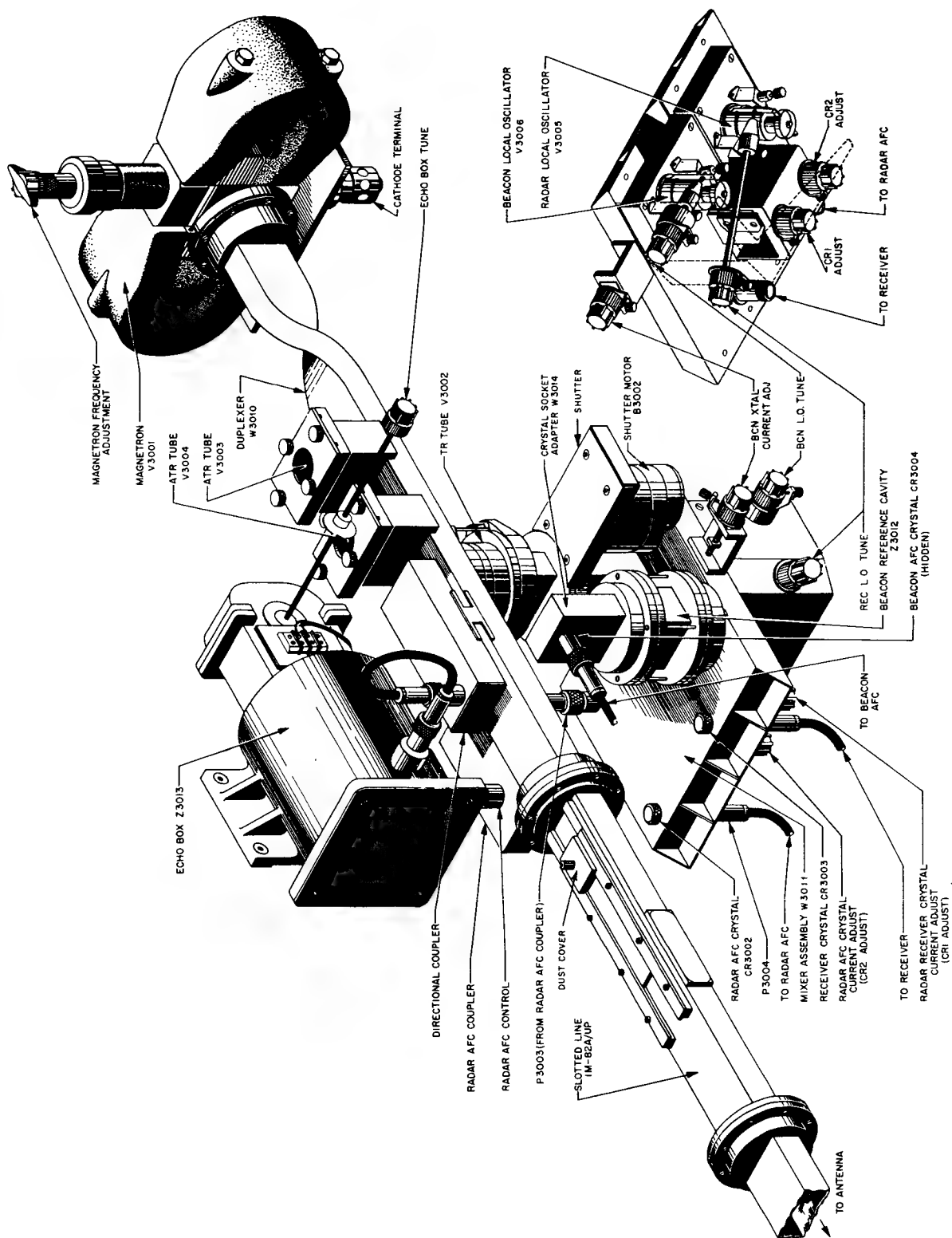
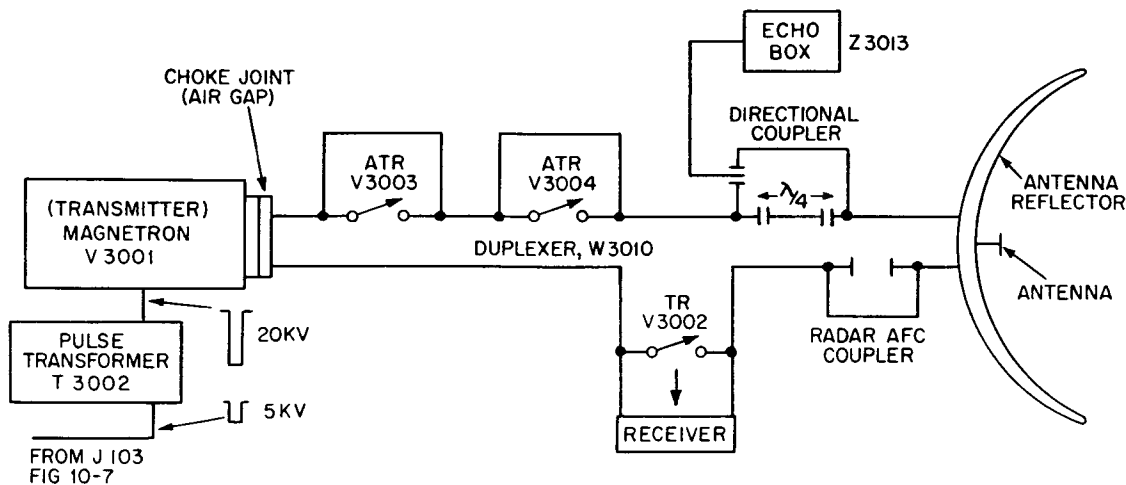


Figure 10-9.—R-f section of receiver-transmitter in AN/SPS-10D.

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Figure 10-10.—Transmitter, block diagram.

The duplexer conducts the magnetron r-f output to suitable waveguide and then to the antenna and the antenna reflector, from which the energy is radiated into space. A portion of the transmitted energy strikes a target or targets and returns (by reflection) to the antenna reflector. This energy travels through the duplexer and through t-r tube, V3002, to the receiver during intervals when the magnetron is not operating.

The 7-8 secondary of T3002 produces a low voltage positive triggering pulse for the stc circuit and the beacon afc circuit in the radar receiver. This circuit is explained in chapter 11 of this training course.

Spark gap, E3006, is a protective device which arcs-over at 2200 volts peak. In case of an open in the magnetron ground lead, the gap will arc-over to prevent excessive transient voltages from appearing in the circuit and causing a breakdown of the capacitor (C3003 and C3004) dielectric material.

MICROWAVE SWITCHING

The duplexer, W3010, of AN/SPS-10D (fig. 10-11) makes possible transmission and reception from a single antenna. It does this without damaging the receiver during transmission of the high-power pulse and without undue loss of the received echo signal in the transmitter during reception.

The duplexer uses an arrangement of microwave (t-r and a-t-r) switches which distinguish between the transmitted and received pulses by the relative power levels. One t-r (transmit-receive) tube and two a-t-r (anti-transmit-receive) tubes are used. These tubes are

positioned electrically on the duplexer as shown in figure 10-12. The t-r and a-t-r tubes are essentially the same in action, although the a-t-r tube is less critical in design.

The t-r tube V3002 is basically a resonant cavity spark-gap tuned to the transmitter frequency and filled to a low pressure with gas. The switching action of the tube is accomplished automatically by the r-f energy, resulting from the difference in power level between the transmitted pulse on and off condition. The transmitted pulse is sufficiently strong to strike an arc (i.e., form a short circuit) across the gap of the tube. The combination of spark gap and resonant cavity increases the instantaneous voltage across the gap before firing. This causes the tube to fire nearer the beginning of the transmitted pulse, and to present a more complete short circuit during the arc.

In order to increase the t-r tube sensitivity and to ensure complete ionization during each pulse, a -950-volt keep-alive voltage is applied to V3002 at all times. This voltage maintains V3002 at a point just below that required for complete ionization. The high-power transmitter pulse will immediately raise the voltage to a point well above the critical ionization point of V3002 and cause the tube to arc more rapidly and more smoothly. The target echoes contain considerably less power than the transmitted pulse and will not fire the t-r tube during the interval between transmitted pulses.

The spacing of the a-t-r and t-r tubes used in Radar Set AN/SPS-10D is as shown in figure 10-12. Note that the duplexer has two a-t-r tubes spaced one and one quarter wavelengths apart (mid-band). Two tubes are used in order

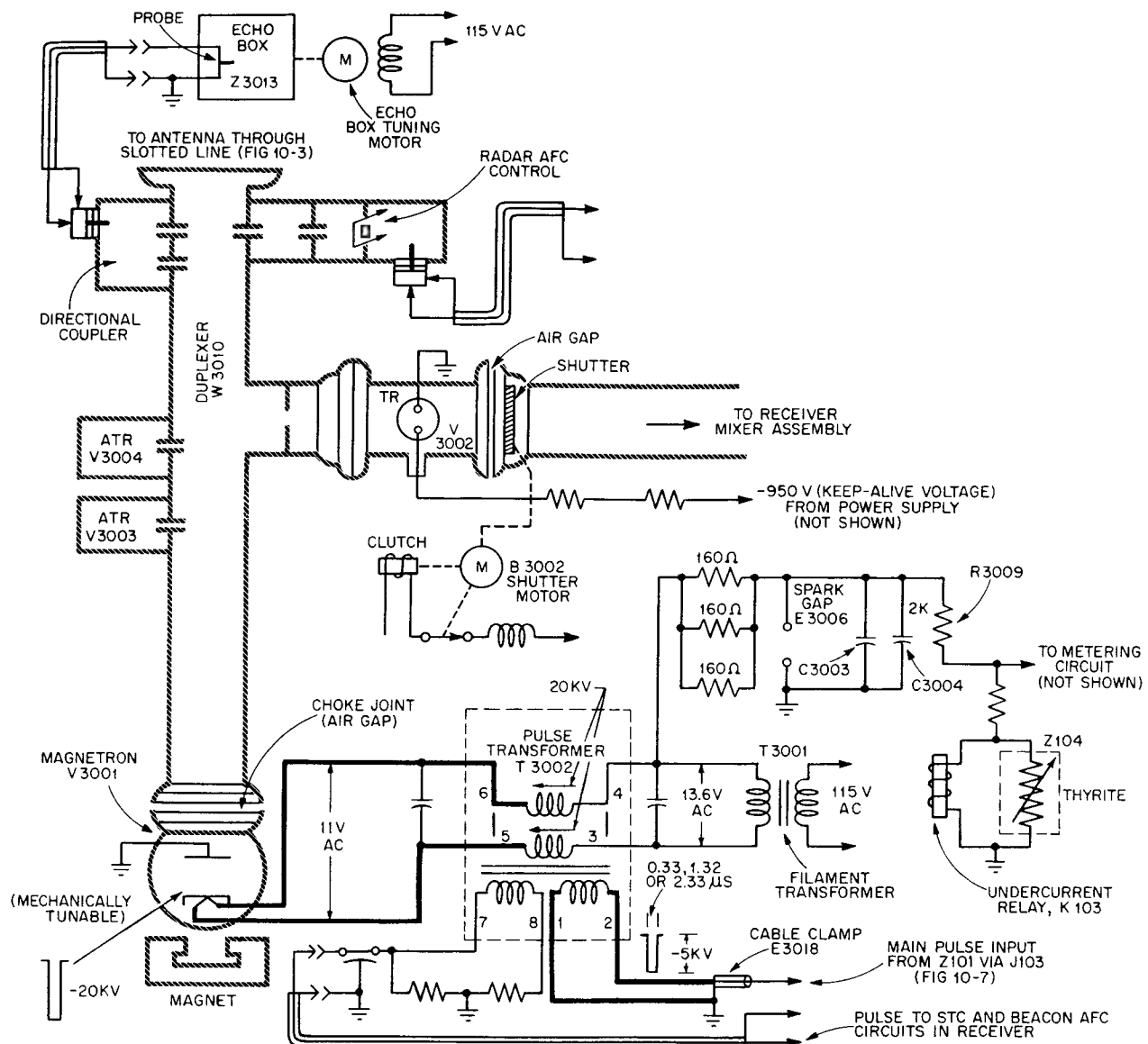


Figure 10-11.—Transmitter section, schematic diagram.

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to ensure effective firing over the full magnetron frequency band. The actual spacing of the tubes is in terms of fractions of the duplexer (waveguide) wavelength which is longer than the free-space wavelength. Because of fringing effects at the waveguide junctions, the actual spacing of these components is determined experimentally.

When the magnetron, V3001, oscillates, the high-power microwave burst passes into the duplexer and energizes the t-r and a-t-r tubes by striking an arc in them. The shorts in the a-t-r tubes (V3003 and V3004) appear across

the waveguide one-fourth wavelength from the open ends. The impedance looking into the a-t-r junctions from points X is infinite and the transmitter energy continues down the waveguide toward the antenna.

The arcing of the t-r tube, V3002, results in a short-circuit one-half wavelength from the t-r junction. Because of the half-wavelength between the short and the duplexer, the short circuit appears to the r-f energy as if it were a closed switch at the opening to the t-r junction (point Y). Thus, the r-f energy continues down the duplexer to the antenna and antenna reflector.

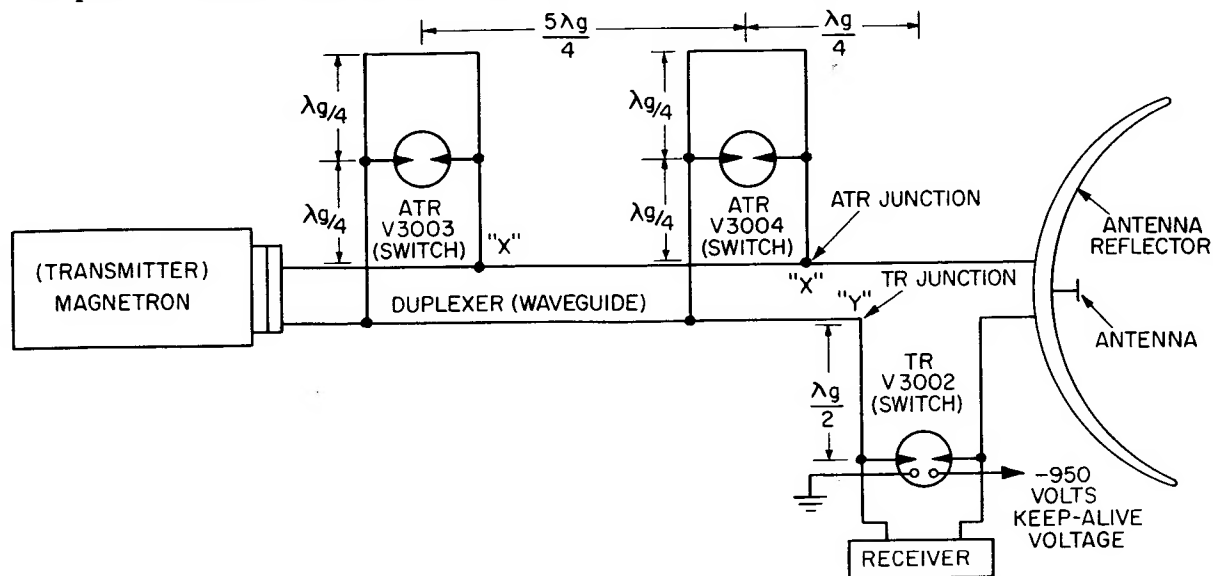


Figure 10-12.—Duplexer (microwave switching). ^{32.183}

The only loss in power encountered in the passing of the magnetron output to the antenna is that required to maintain the arcs in the t-r and a-t-r switches.

The input path to the receiver is short-circuited during the arc-over in V3002 so very little of the transmitted energy enters the receiver during magnetron operation. The t-r tube arc-over does not represent zero resistance but will be of the order of a few ohms. Thus, a small input voltage will be developed across the receiver input terminal. This voltage is well below a value which will damage the receiver and receiver burnout should not occur in spite of the terrific power of the r-f pulse.

When the magnetron, V3001, is off (receive period) the t-r tube, V3002, is open, and the waveguide is not short-circuited at the t-r junction. The received echo pulse will then pass with ease along the matched input path to the receiver.

During reception, the a-t-r tubes (V3003 and V3004) are not energized (open). In this condition, the impedance at points X looking toward the a-t-r switches is zero, since both a-t-r branches now appear as half-wave shorted stubs. The line is effectively short-circuited at points X and the impedance at Y looking toward the transmitter is that seen at the open end of a shorted quarter-wave stub and a five-quarter wavelength shorted stub (both impedances infinite). Thus, all of the received energy (echo) is routed into the receiver.

In some radar system duplexers the a-t-r tubes are not used. Then, the length of the waveguide is adjusted so that an infinite impedance is seen from the t-r junction (point Y) looking toward the transmitter. The path into the receiver is a low impedance and essentially all of the received echo passes to the receiver.

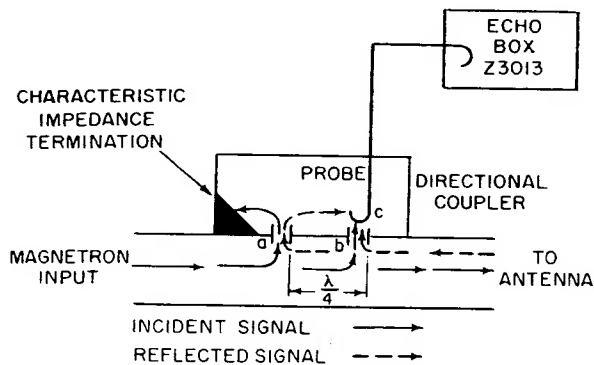
DIRECTIONAL COUPLER AND ECHO BOX

The directional coupler (fig. 10-10) and the echo box, Z3013, function together to provide a means of checking the overall performance of the radar set. Transmitted r-f energy from the waveguide is fed through the directional coupler to the echo box. The echo box stores the energy during transmission and releases it to the receiver immediately after the transmitting period. This received energy from the echo box is displayed on the PPI scope and can be interpreted by the observer to give an indication of the system performance as described earlier.

Directional Coupler

As the name implies, the directional coupler is so connected in the transmission line that either the transmitted energy (traveling down the line) or the reflected energy (traveling in the opposite direction) may be sampled.

The one-way directional coupler (fig. 10-13) samples r-f energy traveling from the magnetron



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Figure 10-13.—Directional coupler and echo box.

to the antenna and rejects energy traveling in the opposite direction.

The unit is coupled to the main waveguide through two small holes located one-quarter wavelength apart. One end of the directional coupler is terminated in its characteristic impedance, and absorbs most of the energy reflected to that end of the coupler. The output from the coupler is taken from a probe at the other end, and fed through a coaxial cable to the echo box probe.

A small portion of the magnetron r-f energy (incident wave) is fed into the two holes on the directional coupler. The voltage at the probe in the directional coupler consists of two components (E_{ac} and E_{abc}). The paths traveled by the two components from the magnetron to the directional coupler probe are approximately equal and the voltages are only slightly out-of-phase. These voltages add at the directional coupler probe, and a large incident voltage is produced at the echo box probe.

There are also two paths for reflected energy which exist in the guide because of slight mismatches in impedance between the duplexer and antenna. Along one path the reflected signal (indicated by dashed arrows) passes from b to c in the directional coupler, while in the other path the reflected signal travels one-quarter wavelength farther to a and an additional one-quarter wavelength back to c. The latter path is one-half wavelength longer than the original path. The two reflected voltage components therefore arrive at the directional coupler probe 180 degrees out-of-phase and cancellation occurs. Thus, the input r-f energy from the magnetron to the echo box probe is essentially free of reflected r-f signal in the waveguide.

The ratio of power traveling up the waveguide (from magnetron to antenna) to power traveling down the guide (from antenna to magnetron) is greater than 15 db. The standing-wave ratio resulting from the insertion of the directional coupler is negligible.

Echo Box

The echo box, Z3013 (fig. 10-13) is equivalent to a high-Q tuned circuit. The energy stored in the echo box during the transmission interval decays exponentially during the receive interval. The time required for the energy to drop to the noise level of the receiver is known as the "echo box ring-time," and depends on two factors: (1) the amount of the transmitted energy stored by the echo box; and (2) the overall noise level of the receiver. The energy stored by the echo box, if it is tuned to the transmitter frequency, is determined by the duration of the transmitted pulse and by the magnitude of the pulse energy.

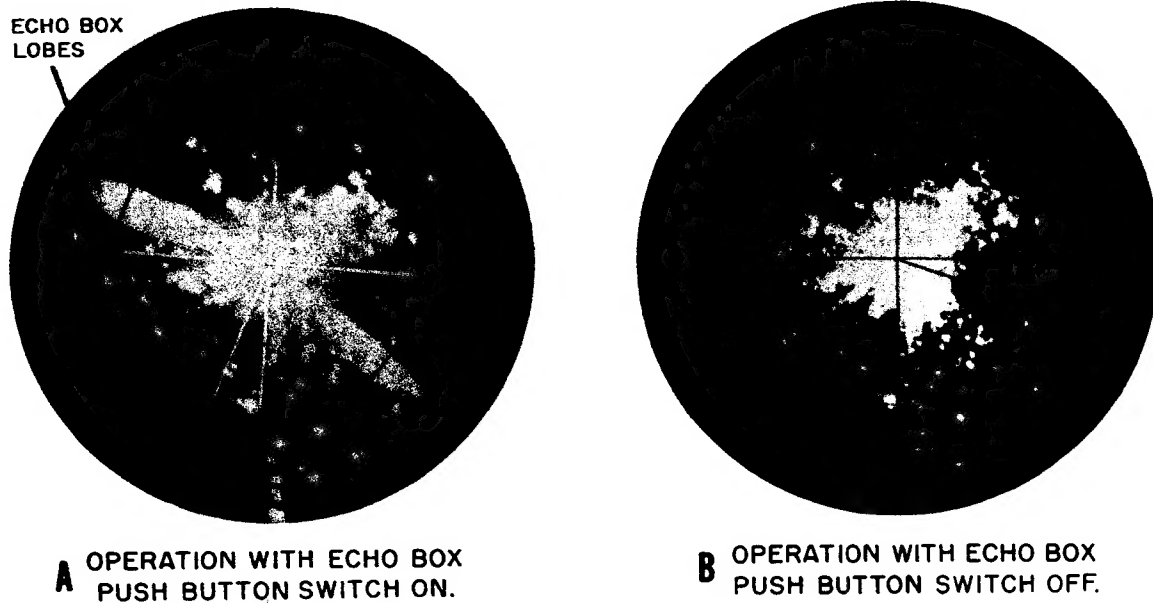
If the power output of the transmitter were decreased, less energy would be stored in the echo box. The discharge of the stored energy after the transmitted pulse would begin at a lower level, and therefore take less time to decay. This would yield a shorter ring-time.

A reduction of the transmitter power (echo box charging energy) to one-half (3 db down) will reduce the ring-time approximately 1 μ s. The noise level of the receiver sets the level at which the ringing is no longer perceptible on the plan position indicator. An increase in the receiver noise level by 3 db will also reduce the ring-time approximately 1 μ s.

Because the magnetron frequency is tunable, the echo box must be tunable over the same frequency range. An echo box tune knob is provided on the receiver-transmitter (fig. 10-9) to manually tune the echo box cavity to the magnetron frequency.

When the equipment is operated from the radar set control (fig. 10-1), the echo box tuning is accomplished by a motor (not shown). The motor is operated by a push button switch on the radar set control panel marked ECHO BOX. The motor drives the echo box tuning shaft so that the tuning sweeps over the entire range of transmitted frequencies. Ringing will occur whenever the resonant frequency of the echo box is the same as the output frequency of the magnetron.

The echo box ring-time indications appear on the plan position indicator as lobes (fig. 10-14, A). These lobes should extend outward on the



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Figure 10-14.—Echo box patterns.

indicator a minimum of 4000 yards. The echo box lobes will appear at a rate of 10 times per minute. When the echo box switch is off, the lobes will not appear in the PPI pattern (fig. 10-14, B).

ANTENNA ASSEMBLY AND ANTENNA CONTROL CIRCUITS

The antenna assembly (fig. 10-15) radiates the pulses of microwave energy from the magnetron, and directs the echo signals to the receiver through the waveguide as discussed. The antenna assembly consists of a truncated parabolic reflector, a pedestal, a feedhorn assembly, and a synchro (located in the antenna pedestal) which provides bearing information.

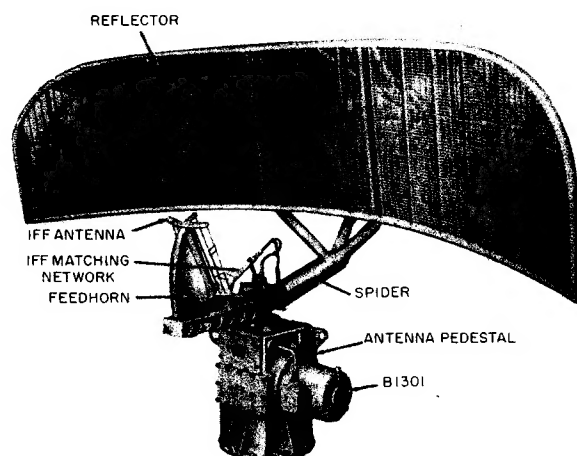
The antenna pedestal also contains a unidirectional 440-volt 60-cycle 3-phase 1-horsepower antenna drive motor, B1301 (fig. 10-16). Power for the motor is applied through manual controller switch S1501, and control antenna switch S1401. The motor turns at 1725 rpm.

An oil-heater, HR1301 (in the antenna pedestal) provides a means of maintaining the ambient temperature of the motor lubricant above 25° C. If the temperature drops below this value, a heater switch (not shown) closes to allow a heater warm-up current to flow through the heater element.

Drive motor B1301 is mechanically coupled to the antenna through a reduction gear train

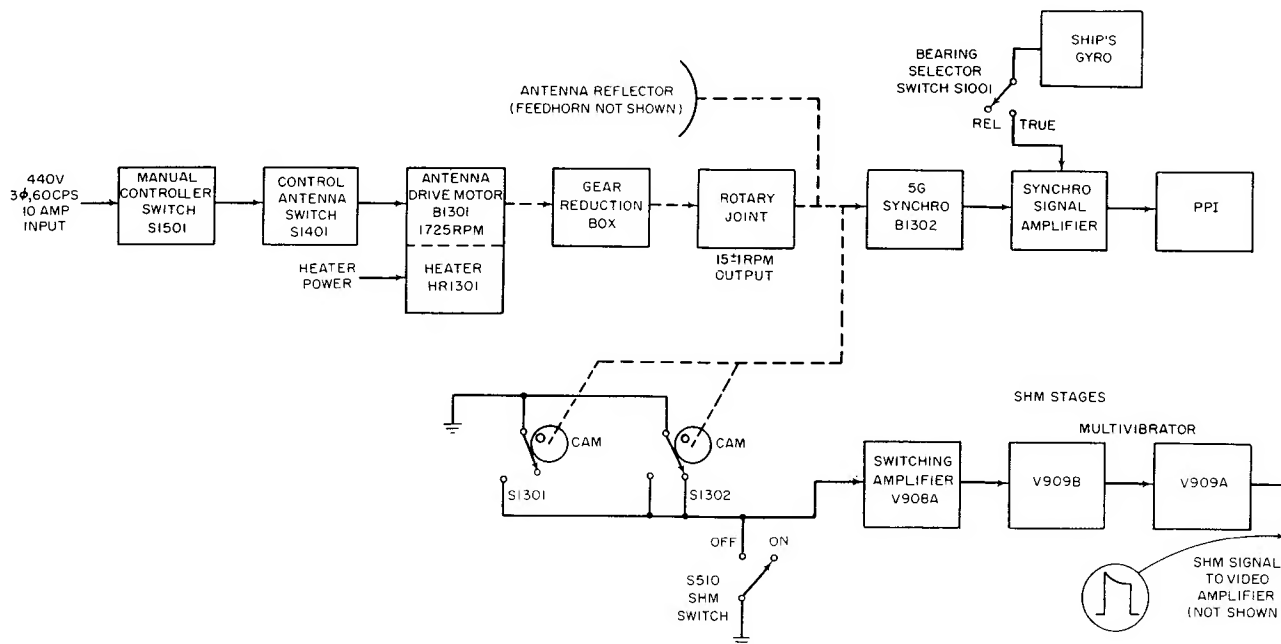
and a rotary joint. The turning of the rotary joint causes rotation of a main shaft (which drives the antenna), a 5G synchro, and two cam-operated microswitches. The gear reduction to the main shaft causes the antenna to turn clockwise at 15 ± 1 rpm.

The main shaft is sufficiently locked by the action of the gear train during rotation to prevent error introduction in the antenna speed by normal forces acting on the antenna reflector. When S1501 or S1401 is open, B1301 does not rotate. The locking feature provided by the gear train when the antenna is not rotating prevents



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Figure 10-15.—Antenna assembly.



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Figure 10-16.—Antenna pedestal and antenna control circuit block diagram.

the reflector from drifting during high winds, and acts as a safety during maintenance.

Synchro B1302 is driven at the same speed as the antenna reflector, and provides an output voltage to the synchro signal amplifier which is proportional to the position of the antenna reflector. During alignment, the antenna reflector is rotated (by operating S1501) until it points directly toward the ship's bow. The synchro, B1302, is then rotated to produce an electrical zero. In operation, the antenna reflector and B1302 maintain correspondence. The B1302 output is fed through the synchro signal amplifier to the PPI scope. This voltage drives the sweep on the indicator at the same rate and through the same angle as the antenna reflector, and bearing information relative to the ship's bow can be read from the indicator.

The bearing selector switch, S1001, provides a means of selecting either true- or relative-bearing information for presentation on the plan position indicators. When S1001 is in the TRUE position (opposite to the position shown), gyro compass information and relative bearing information (from B1302) are combined in the synchro signal amplifier. With these inputs, the synchro signal amplifier computes true-bearing information for the plan position indicators.

The antenna assembly also contains two-cam-operated microswitches, S1301 and S1302. These switches produce the ship's heading

marker (shm) on the indicator each time the antenna reflector crosses the ship's bow. The marker appears as a group of dashed lines which extend outward on the ship's trace. An shm switch, S510, provides on-off control of the marker signals.

When S510 is in the ON position, the operation of the shm stages (V908 and V909) is controlled by S1301 and S1302. The cams which operate these switches rotate at the same rate as the antenna reflector (15 rpm).

As the antenna rotates past 000 degrees relative, S1301 momentarily opens, and the ground is removed from the switching amplifier, V908A, permitting the shm stages to operate. In this condition, a 100-kc shm signal is fed from multi-vibrator, V909A, through the video amplifier (not shown) to the indicator, where it appears on the indicator sweep as a 100-kc intensity modulation.

The cam arrangement of S1301 and S1302 is designed so that there is a time difference between the operation of the switches. The S1302 cam is set so that as soon as the antenna reflector rotates past 000 degrees, S1302 will close and shunt S1301, thereby replacing the ground on V908A and cutting off the shm output. Thus, S1302 prevents the occurrence of an erroneous shm on the display due to the rise and fall time of a single cam operated microswitch.

The remaining portions of the AN/SPS-10D are treated in chapter 11 of this training course.